

Research Article

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Studies on the management and exploitation of aquatic weeds for manurial value for sustaining soil health

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Summary

The experiment was completed in three stages. Representative samples of water cabbage (*Limnocharis flava*), coir pith, water hyacinth (*Eichhornia crassipes*) and farm wastes (dried leaves and pseudostem of banana) were collected and analysed for bio-chemical composition. Then the four substrates were treated with four inoculants viz., *Trichoderma reesei*, *Pleurotus sajor-caju*, composting inoculums and commercial enzyme cocktail. The resultant composts were analyzed for the manurial value so as these weed plants and farm residues can be efficiently utilized for the preparation of composts which can induce the soil nutrient content and health. From the study water cabbage was the best substrate in terms of their chemical composition followed by water hyacinth.

Key words : Management, Exploitation, Aquatic weeds, Soil health

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Introduction

The most widely available and also the most wasted energy source are a wide variety of agricultural wastes. Apart from the direct wastes from farm, weed plants can also be included in farm wastes. Agriculture wastes recycling can bring tremendous benefits to agriculture and land management in long run. In addition there are the benefits of a cleaner environment, a healthier habitat and an intelligent use of all available recyclable resources without condemning them as wastes. Management of this voluminous residue is a major challenge to farmers and there is a need to explore some eco-friendly, low cost, easily adoptable residue management strategies that can replenish the soil of its nutrients.

Many alternatives for the disposal of the organic wastes have been proposed, composting being one of the most attractive on account of its low environmental impact and cost as well as its capacity for generating a product valuable for increasing soil fertility (Pascual *et al.*, 2002). Water cabbage (*Limnocharis flava*) is an emergent plant in rice cultivated areas that may become noxious over the growing areas (Karim *et al.*, 2004). The water hyacinth, (*Eichhornia crassipes*) is considered to be one of the most invasive plant species worldwide (Gopal, 1987). The aim of this study, therefore, was the management and exploitation of these two important aquatic weeds and additional two substrates viz., coirpith and farm waste (banana pseudostem and dry leaves) found in

Kerala for manurial value for sustaining soil health using four inoculants.

Resource and Research Methods

Collection and proximate analysis of samples for characterization :

Representative samples of water cabbage (*Limnocharis flava*), water hyacinth (*Eichhornia crassipes*), farm wastes (dried leaves and pseudostem of banana) and coir pith from different locations were collected and were then subjected to chemical characterization for identifying the constitutional makeup.

Design: Completely Randomized Design (CRD)

Treatments: 4

Replication: 5

The substrates used in the study were

S₁ Water cabbage

S₂ Coir pith

S₃ Water hyacinth

S₄ Farm waste

Conversion into compost

Method of composting :

The method followed was aerobic heap method with 100 kg of biomass was mixed with 10 kg of cowdung. After the completion of thermophilic stage, 1 kg of the following inoculants were added to the substrates. The inoculants used in the study were:

I₁ -*Trichoderma reesei*

I₂ -*Pleurotus sajor-caju*

I₃ - Composting inoculum developed by the Dept. of Agricultural Microbiology College of Agriculture, Vellayani

I₄ - Commercial enzyme cocktail (Cellulase / pectinase and laccase)

Design : Completely Randomized Design (CRD)

Treatments: 16 (4x4 Factorial)

S₁ - Water cabbage I₁ - *T. reesei*

S₂ - Coir pith I₂ - *P. sajor-caju*

S₃ - Water hyacinth I₃ - Composting inoculum

S₄ - Farm waste I₄ - Commercial enzyme cocktail

Replication: 3

Evaluation of the resultant composts through pot culture :

The resultant compost from the previous stage was then evaluated for its performance as manure in pot culture experiment.

Details of the pot culture experiment :

Design: Completely Randomized Design (CRD)

Treatments: 19

Replications: 3

Crop : Amaranthus

Variety: Arun

Treatment application :

After two weeks of sowing, nineteen treatments including POP recommendation, vermicompost, prepared sixteen compost combinations (Experiment I) and one absolute control were imposed to the pots according to the technical programme. Details of the treatments are presented in Table A.

Table A: Treatment details

Treatments	Details
T ₁	N, P, K as per POP – 1.36 g N+ 1.56 g P+ 0.52 g K
T ₂	100 % N as vermicompost - 15 g
T ₃	100 % N as compost (C ₁) - 14.3 g
T ₄	100 % N as compost (C ₂) -10.73 g
T ₅	100 % N as compost (C ₃) - 7.97 g
T ₆	100 % N as compost (C ₄) -11.87 g
T ₇	100 % N as compost (C ₅) - 26.1 g
T ₈	100 % N as compost (C ₆) - 23.25 g
T ₉	100 % N as compost (C ₇) - 27.9 g
T ₁₀	100 % N as compost (C ₈) - 26.57 g
T ₁₁	100 % N as compost (C ₉) - 16.9 g
T ₁₂	100 % N as compost (C ₁₀) -15.1 g
T ₁₃	100 % N as compost (C ₁₁) - 10.2 g
T ₁₄	100 % N as compost (C ₁₂) - 10.73 g
T ₁₅	100 % N as compost (C ₁₃) - 21.5 g
T ₁₆	100 % N as compost (C ₁₄) - 18.6 g
T ₁₇	100 % N as compost (C ₁₅) - 7.97 g
T ₁₈	100 % N as compost (C ₁₆) - 16.91 g
T ₁₉	Absolute control (no fertilizer)

Research Findings and Discussion

With respect to the nutrient content of the various substrates viz., water cabbage, coir pith, water hyacinth and farm waste, a significant difference was noticed.

Water cabbage recorded the highest value of N, P and K while coir pith was found to be low as inferred from the Table 1. The highest nutrient content of aquatic weed *L. flava* might be due to the accumulation of the nutrients from wet land ecosystem. Species of plant and time of year influence the nutrient content of aquatic weeds like water cabbage (Sutton and Portier, 1989).

The C:N ratio of different substrates ranged from 16.98 to 243.59 (Table 1). The wider C:N ratio of 243.59 was recorded by substrate S_2 (coir pith) which was significantly different from others followed by S_4 (farm waste) (86.95). The narrow C:N ratio was recorded by S_1 (water cabbage) with mean value of 16.98 and statistically at par with S_3 (water hyacinth) with mean value of 27.49. Regarding the C:N ratio, the widest value was reported by the substrate coir pith.

All the substrates were analysed for the heavy metals viz., Pb, Cd, Ni and Sn content. The data on heavy metal contents of the substrates are presented in the Table 2. All the heavy metal content did not differ significantly between the degradable wastes used however, they were significantly different on Ni content. All the wastes used were at par with each other except coir pith which registered high Ni content of 0.97 mg kg^{-1} .

Compost prepared from water cabbage and composting inoculum reported a high total N content (Table 3) due to the positive interaction between the substrate and inoculum. Generally the total N concentration increased during composting due to the concentration effect whereas the highest P content was reported in water hyacinth and composting inoculum. In

the case of K also, a significant variation was noticed with respect to substrate, inoculants and their interactions. C: N ratio is an important factor deciding the availability of nutrients. Table 3 depicting the C: N ratio, the narrowest ratio was recorded in the compost produced out of the combination of water cabbage + composting inoculum and water hyacinth + composting inoculum. The decrease in C: N ratio over time might have been also attributed to the rapid decrease in C-substrates by the utilization of fungus in composting inoculum. Similar results were reported by Nedagwa *et al.* (2000)

Microbial parameter such as (Table 4) and cellulase activity can be considered as indicators of compost maturity. Compost of water cabbage with composting inoculum recorded high cellulase activity. The increased cellulase activity depicts an increased rate of cellulose degradation and thus, the maturity of compost. The lowest maturity period in water cabbage and composting inoculum compost (44 days) indicated that the time taken for composting to reach maturity was less than others. A two fold increase in the degradation potential was noticed in this compost when compared to the compost produced out of coir pith with commercial enzyme cocktail which recorded the more maturity period.

From this study it was observed that the compost produced with the combination of banana pseudostem + dry leaves and *P. sajor-caju* reported to have detectable levels of Pb and Cd. Whereas in the case Ni content, coir pith and composting inoculum has reported highest Ni content. In the case of tin the highest value was noticed with water hyacinth and commercial enzyme

Table 1 : Major nutrients of different substrates

Substrates	Total nitrogen (%)	Total phosphorus (%)	Total potassium(%)	C:N ratio
S_1	2.74	0.30	0.33	16.98
S_2	0.07	0.02	0.01	243.59
S_3	1.59	0.30	0.25	27.49
S_4	0.59	0.15	0.24	86.95
C.D. (P=0.05)	0.035	0.025	0.032	14.576

Table 2 : Heavy metals of different substrates

Substrates	Pb (mg kg^{-1})	Cd ($\mu\text{g kg}^{-1}$)	Ni (mg kg^{-1})	Sn ($\mu\text{g kg}^{-1}$)
S_1	Non-detectable	Non-detectable	0.55	Non-detectable
S_2	0.01	0.02	0.97	Non-detectable
S_3	1.15	0.06	0.57	0.56
S_4	0.03	0.16	0.51	Non-detectable
C.D. (P=0.05)	-	-	0.288	-

cocktail. Although all the compost showed different levels of Pb, Cd, Ni, and Sn all the composts were reported to have heavy metals below the critical limits as per the specifications of FAO (Table 5).

With respect to the yield as inferred from Table 6, treatments imparted significant effect on the yield of the crop. The treatments received 100 per cent N as compost prepared from water hyacinth and composting inoculum combination and water cabbage and composting inoculum

combination recorded the highest yield. Water hyacinth has recorded the highest yield among the substrates. The observations are strongly agreed with Ainika *et al.* (2012) who reported that the growth and yield parameters of amaranthus accessed were significantly increased in response to the application of organic manure.

Regarding the effect of composts on soil electrical conductivity the highest value of for EC was reported with compost (farm waste and commercial enzyme

Table 3: NPK content of the composts as influenced by substrates, inoculants and their interactions

Treatments	Total N (%)	Total P (%)	Total K (%)
S ₁ I ₁	2.12	0.50	0.47
S ₁ I ₂	2.58	0.48	0.67
S ₁ I ₃	3.83	0.41	0.37
S ₁ I ₄	2.40	0.38	0.79
S ₂ I ₁	1.21	0.17	0.16
S ₂ I ₂	1.22	0.15	0.12
S ₂ I ₃	1.16	0.08	0.19
S ₂ I ₄	1.13	0.13	0.13
S ₃ I ₁	1.77	0.48	0.72
S ₃ I ₂	2.03	0.51	0.69
S ₃ I ₃	2.98	0.75	1.87
S ₃ I ₄	2.81	0.50	0.75
S ₄ I ₁	1.58	0.27	0.56
S ₄ I ₂	1.69	0.40	0.79
S ₄ I ₃	2.21	0.43	0.43
S ₄ I ₄	1.74	0.39	0.75
S ₁	2.73	0.44	0.57
S ₂	1.18	0.13	0.15
S ₃	2.40	0.56	1.01
S ₄	1.81	0.37	0.63
I ₁	1.67	0.35	0.48
I ₂	1.88	0.38	0.57
I ₃	2.55	0.42	0.71
I ₄	2.02	0.35	0.63
CD-S I (P=0.05)	0.252	0.076	0.174
CD -S (P=0.05)	0.126	0.038	0.087
CD-I (P=0.05)	0.126	0.038	0.087

S₁ Water cabbage
 S₂ Coir pith
 S₃ Water hyacinth
 S₄ Farm wastes

I₁ *Trichoderma reesei*
 I₂ *Pleurotus sajorajju*
 I₃ Composting inoculum
 I₄ Commercial enzyme cocktail

cocktail). This result can be interpreted that the application of composts did not drastically increase the EC as the values noted were below 4 dSm⁻¹.

In the case of bacteria the compost water cabbage and composting inoculum has proved their efficiency individually in increasing bacterial count. The effect of substrate was found to be significant on the bacterial population while inoculant did not affect. Addition of composted water cabbage increased the bacterial activity representing a shift in microbial response resulting in changes in substrate availability.

Present study reveals that the N content of the

plants was significantly influenced by the treatments. Application of compost prepared from farm waste and *T. reesei* has resulted the highest N content in the plants. This might be due the high N content of the compost as well as the readily available form of ions due to the particular interaction of inoculant and the substrate. Saxena *et al.* (2001) found that the application of N helped in increasing the vegetative growth of plants and also plant dry matter in soybean.

With respect to the micro nutrient status, the highest Fe content was recorded by compost prepared from coir pith and composting inoculum. Substrates imposed

Table 4 : Soil properties, microbial parameter and maturity indices of resultant composts

Treatments	Total N (%)	Cellulase activity	Maturity period(days)	C:N ratio
S ₁ I ₁	2.12	308.14	49.00	20.93
S ₁ I ₂	2.58	119.15	46.33	12.94
S ₁ I ₃	3.83	407.68	44.33	5.86
S ₁ I ₄	2.40	316.86	47.67	9.78
S ₂ I ₁	1.21	345.80	80.33	30.64
S ₂ I ₂	1.22	387.42	83.33	30.35
S ₂ I ₃	1.16	401.39	79.67	13.86
S ₂ I ₄	1.13	394.37	86.67	14.58
S ₃ I ₁	1.77	381.45	65.67	16.82
S ₃ I ₂	2.03	322.87	66.00	10.56
S ₃ I ₃	2.98	232.76	63.00	8.24
S ₃ I ₄	2.81	304.50	67.67	9.69
S ₄ I ₁	1.58	293.02	77.33	20.31
S ₄ I ₂	1.69	200.60	78.33	16.91
S ₄ I ₃	2.21	390.38	74.67	13.64
S ₄ I ₄	1.74	352.57	78.00	14.94
S ₁	2.73	262.96	46.83	12.38
S ₂	1.18	382.25	82.50	22.36
S ₃	2.40	310.39	65.58	11.33
S ₄	1.81	309.14	77.08	16.45
I ₁	1.67	332.10	68.08	22.17
I ₂	1.88	232.51	68.50	17.69
I ₃	2.55	358.05	65.42	10.40
I ₄	2.02	342.07	70.00	12.25
CD-S I (P=0.05)	0.252	61.622	1.248	2.319
CD -S (P=0.05)	0.126	30.811	0.624	1.159
CD-I (P=0.05)	0.126	30.811	0.624	1.159

Cellulase activity- μg glucose hydrolyzed $\text{g}^{-1}\text{hr}^{-1}$

significant influence on Fe content. Regarding Mn content, water hyacinth and composting inoculum has resulted in the highest value. Substrate as well as inoculants imparted significant variations. Zn is one of the most important micronutrient needed for the metabolic activities of the plants. The highest Zn content was recorded by coir pith and *T. reesei* which was at par with coir pith and composting inoculum. Substrates and inoculants also significantly influenced the Zn content. Kler *et al.* (2002) also reported similar results as on micro nutrients viz., Fe, Cu, Zn and Mn content in plants under organic farming over the chemical fertilizer and control. More extractable micronutrients might be attributed to chelating action of organic compounds released during decomposition of organic sources, which increased the availability of micronutrients by preventing fixation, oxidation, precipitation and leaching. Similar results have

been reported by Hao and Chang (2003).

Zymes such as urease, dehydrogenase and aryl sulphatase and cellulase were measured indirectly. The highest activity with the application of water hyacinth compost might be attributed to high availability of easily degradable substrate and varying nutrient contents which ultimately resulted in the spurt of ureolytic bacteria and ultimately increasing the urease activity.

From the study it was evident that the application of water hyacinth and composting inoculum had reported to increase the dehydrogenase activity in soil which was similar in effect to water cabbage and composting inoculum. Similar effects were reported by Bundela *et al.* (2010) who described a generalized short term to medium term increase in dehydrogenase enzyme with organic inputs. The increased production and release of growth promoting substance by the application of water

Table 5 : Heavy metal content of the composts as influenced by substrates, inoculants and their interactions

Treatments	Pb (mg kg ⁻¹)	Cd (µg kg ⁻¹)	Ni (mg kg ⁻¹)	Sn (µg kg ⁻¹)
S ₁ I ₁	N.D	N.D	0.510	N.D
S ₁ I ₂	N.D	N.D	0.039	N.D
S ₁ I ₃	N.D	N.D	0.414	N.D
S ₁ I ₄	N.D	N.D	0.178	N.D
S ₂ I ₁	0.027	N.D	0.053	N.D
S ₂ I ₂	0.041	N.D	0.082	N.D
S ₂ I ₃	0.024	N.D	0.520	N.D
S ₂ I ₄	0.028	N.D	0.132	N.D
S ₃ I ₁	0.193	2.607	0.127	0.678
S ₃ I ₂	0.095	3.430	0.005	0.578
S ₃ I ₃	0.071	2.526	0.214	0.712
S ₃ I ₄	0.124	3.583	0.177	0.877
S ₄ I ₁	0.205	5.649	0.040	N.D
S ₄ I ₂	0.208	6.423	0.074	N.D
S ₄ I ₃	0.108	5.115	0.422	N.D
S ₄ I ₄	0.158	5.458	0.082	N.D
S ₁	-	-	0.285	-
S ₂	-	-	0.197	-
S ₃	-	-	0.131	-
S ₄	-	-	0.155	-
I ₁	-	-	0.182	-
I ₂	-	-	0.050	-
I ₃	-	-	0.393	-
I ₄	-	-	0.143	-
CD- SI (P=0.05)	-	-	0.0248	-
CD-S (P=0.05)	-	-	0.0124	-
CD-I (P=0.05)	-	-	0.0124	-

hyacinth and composting inoculum compost might have contributed to the intense proliferation of microbial growth resulting in higher dehydrogenase activity (Castaldi *et al.*, 2008).

In the present study it was observed that compost prepared from water hyacinth and composting inoculum

was reported to have increased aryl sulphates activity in post harvest soil sample. The substrate coir pith and inoculum *Pleurotus* have influenced the aryl sulphatase activity individually. Similar effects with the application of compost were reported by Eivazi *et al.* (2003).

The presence of heavy metals in soil after compost

Table 6 : Effects of treatments on yield, soil properties, microbial population and plant contents of nutrients						
Treatments	Yield (g /plant)	EC (μSm^{-1})	Bacteria $\times 10^6$ cfu	Total nitrogen %	Fe mg kg^{-1}	Zn mg kg^{-1}
T ₁	128.30	178.40	35.67	1.40	473.43	29.87
T ₂	84.70	166.69	124.67	2.69	322.19	29.69
T ₃ (S ₁ I ₁)	103.30	176.70	137.67	1.75	463.42	31.43
T ₄ (S ₁ I ₂)	82.20	194.84	126.00	2.02	463.03	29.68
T ₅ (S ₁ I ₃)	154.50	171.87	137.33	2.46	468.63	40.50
T ₆ (S ₁ I ₄)	96.50	182.63	113.33	2.13	459.37	37.90
T ₇ (S ₂ I ₁)	86.00	162.68	90.00	1.36	320.13	54.03
T ₈ (S ₂ I ₂)	76.40	171.45	82.00	1.90	298.00	35.53
T ₉ (S ₂ I ₃)	101.20	135.11	118.00	2.02	482.57	50.00
T ₁₀ (S ₂ I ₄)	97.20	177.39	97.00	1.83	348.00	27.84
T ₁₁ (S ₃ I ₁)	100.80	178.99	111.00	1.89	358.83	37.38
T ₁₂ (S ₃ I ₂)	97.40	181.41	98.67	1.85	437.27	34.43
T ₁₃ (S ₃ I ₃)	159.54	156.90	146.33	1.90	408.67	32.54
T ₁₄ (S ₃ I ₄)	99.70	166.30	128.67	2.09	408.50	39.72
T ₁₅ (S ₄ I ₁)	106.20	181.44	94.00	2.93	331.30	33.06
T ₁₆ (S ₄ I ₂)	90.20	180.69	89.00	2.46	329.60	29.01
T ₁₇ (S ₄ I ₃)	101.40	159.63	100.67	2.41	302.57	35.66
T ₁₈ (S ₄ I ₄)	99.30	196.36	93.00	2.61	274.90	17.86
T ₁₉	49.50	119.35	25.00	0.95	185.93	14.80
S ₁	109.12	181.51	128.58	2.09	463.61	34.88
S ₂	90.17	161.67	96.75	1.78	362.18	41.85
S ₃	114.36	170.90	121.17	1.93	403.32	36.02
S ₄	99.28	179.53	94.17	2.60	309.59	28.90
I ₁	99.07	174.95	108.17	1.98	368.42	38.97
I ₂	86.55	182.10	98.92	2.06	381.98	32.16
I ₃	127.17	155.58	125.58	2.20	415.61	39.68
I ₄	98.14	180.67	108.00	2.17	372.69	30.83
CD - T/ SI (P=0.05)	29.98	NS	39.322	0.617	164.807	13.776
CD -S (P=0.05)	14.99	NS	19.66	0.309	82.403	6.888
CD-I (P=0.05)	14.99	16.217	NS	NS	NS	6.888

NS= Non-significant

application were influenced by the application of composts. No detectable levels of Pb in soil was reported in this study by the application of composts prepared from water cabbage. This might be due to the absence of this toxic metal in the substrate itself. Coir pith composts resulted in lower value for Pb because it might have been successfully removed by adsorption on coir pith. With respect to Cd, compost prepared from coir pith and composting inoculum was reported to have contributed to Cd content where as in Ni, coir pith and *T. reesei*. Even though some detectable levels of heavy metals are reported, their concentration in the post harvest soil samples are very below the permissible

tolerance levels as suggested by Mellsted (1973) and Naidu *et al.* (1996).

Conclusion :

In conclusion it was inferred from the study that water cabbage was the best substrate in terms of their chemical composition followed by water hyacinth. Water cabbage + composting inoculum was recorded as the best compost followed by water hyacinth + composting inoculum. With regards to inoculants used on different substrates, composting inoculum was found to be the most effective for composting the agrowastes. The heavy metal accumulation is one of

Table 7 : Effect of treatments on biological properties of the soil			
Treatments	Urease activity	Dehydrogenase activity	Aryl sulphatase
T ₁	152.96	198.46	0.022
T ₂	233.02	216.38	0.020
T ₃ (S ₁ I ₁)	217.95	158.59	0.018
T ₄ (S ₁ I ₂)	203.82	129.34	0.032
T ₅ (S ₁ I ₃)	209.59	248.45	0.015
T ₆ (S ₁ I ₄)	190.61	139.74	0.028
T ₇ (S ₂ I ₁)	137.91	165.35	0.029
T ₈ (S ₂ I ₂)	156.63	159.16	0.031
T ₉ (S ₂ I ₃)	184.78	168.71	0.028
T ₁₀ (S ₂ I ₄)	171.29	92.22	0.017
T ₁₁ (S ₃ I ₁)	149.19	133.31	0.016
T ₁₂ (S ₃ I ₂)	152.36	192.39	0.023
T ₁₃ (S ₃ I ₃)	248.68	252.34	0.037
T ₁₄ (S ₃ I ₄)	187.45	138.48	0.017
T ₁₅ (S ₄ I ₁)	148.62	160.74	0.023
T ₁₆ (S ₄ I ₂)	148.13	132.06	0.016
T ₁₇ (S ₄ I ₃)	200.30	151.26	0.017
T ₁₈ (S ₄ I ₄)	195.68	195.94	0.018
T ₁₉	140.02	67.54	0.016
S ₁	205.49	169.03	0.021
S ₂	162.65	146.36	0.03
S ₃	184.42	179.13	0.023
S ₄	172.18	160.00	0.019
I ₁	163.42	154.50	0.022
C.D. (P=0.05)			

the most dangerous challenge in exploiting weed plants as compost substrates; meanwhile the present study did not show any heavymetal accumulation beyond the permitted limit.

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